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Sixth Quarterly Progress Report
on
THE TRANSFORMATION OF AUSTENITE UNDER EXTERNALLY
APPLIED TENSILE STRESS

for the Period June 1, 1953 to August 31, 1953

by

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October 15, 1953

Contract No. Nonr - 266(13)

Columbia University

SIXTH QUARTERLY PROGRESS REPORT
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THE TRANSFORMATION OF AUSTENITE UNDER EXTERNALLY APPLIED TENSILE STRESS

This report constitutes a summary of work done on the isothermal transformation of austenite to low temperature bainite (at 450°F) in AISI 1085 steel.

Studies were made under no stress and an average of 60,000 psi only, because a detailed study of the effect of various different magnitudes of stresses on transformation had already been made on low temperature bainite of this steel and had been previously reported.^{(1) (2)} The main purpose of this study is to investigate the change in the microstructure of bainite as revealed by electron photomicrographs and electron diffraction patterns. These results will be reported in the next quarterly report.

Experimental procedure for these experiments are similar to those reported previously.^{(1) (2)}

Experimental Results:

The amount of bainite formed due to isothermal transformation is plotted vs. log-time under no stress and an average stress of 60,000 psi and is shown in Fig. 1.

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- (1) Third Quarterly Progress Report, February 17, 1953.
(2) Fourth Quarterly Progress Report, April 30, 1953.

In Fig. 2 is plotted the $\log_e (1-x)$ vs. time (t) for no stress and a 60,000 psi stress, where x is the fractional amount of bainite formed in time t .

In Table I is given the stress applied, isothermal holding times and other relevant informations regarding the transformation of AISI 1085 steel at 450°F.

Using the data of previous experiments, the effect of an average stress of 60,000 psi in shifting the no-stress T-T-T curve of AISI 1085 steel in the lower bainite transformation range is constructed and is shown in Fig. 3.

Discussion of Results:

It is quite evident from Fig. 1 that under a stress of about 60,000 psi both the beginning and ending times of transformation are shortened and these results are given in Table II.

It can be observed from Fig. 2 that the rate of decomposition of residual austenite $\left\{ -\frac{1}{1-x} \cdot \frac{dx}{dt} \right\}$ increases up to a certain value and then becomes fairly constant. The constant rate of decomposition of residual austenite is found to be virtually unaffected by an applied stress of 60,000 psi. Though the constant rate of decomposition of residual austenite is not affected by a stress of 60,000 psi, the constant rate is attained at a much earlier stage of transformation in the case of transformation under stress in comparison to transformation under no stress. In the cases of transformations under no stress, and a stress of 60,000 psi the constant rates are attained when 48% and 28%, respectively, of austenite have decomposed.

The beginning (1%) and ending (99%) curves of isothermal transformation in the lower bainite range as affected by a stress of about 60,000 psi are superimposed on those under no stress and are shown in Fig. 3. The figure indicates the large effect of stress in shifting the lower bainite region of the T-T-T curves to the left, i.e., for shorter isothermal transformation times. Also it indicates the possibility of obtaining 99% transformation product under a stress of about 60,000 psi in the upper bainite range of 750°-850°F in a period of time sufficient to produce only 1% transformation product under no stress.

Metallographic examination of the microstructures of the specimens shows that the structures formed at this low temperature bainite range are very fine and acicular. The effect of stress is revealed in the structure as a definite preferred orientation effect in the bainite needles. This is shown in Fig. 4.

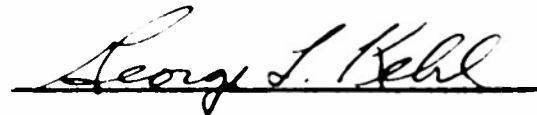
In Fig. 5 is shown a comparative study of microstructures of AISI 1085 steel transformed isothermally to partially bainitic structures at 450°F, 535°F and 700°F, both under no stress and a stress of 60,000 psi stress. This series of microstructures indicate the increase in the acicularity and fineness of the structure with lowering of bainite formation temperature. Also these photomicrographs clearly show the preferred orientation in the bainite structure as induced by applied stress.

Future Work:

Extensive work is now well under way on all the three steels investigated so far, i.e., AISI 1085, 4340 and 1045, as regards to a microstructure investigation under the electron microscope. In the next

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report the results of this investigation will be reported.

A handwritten signature in cursive script, reading "George L. Kehl", is written over a solid horizontal line.

George L. Kehl

Project Director

Table I - Range of Transformation Time and Applied Stresses Relative to AISI 1085 Steel.

Austenitizing Treatment	Isothermal Salt Bath		Range of Isothermal Transformation Time, Sec.	Range of Applied Stress p.s.i.	Austenitic Grain Size at 1620°F A.S.T.M.
	Temperature of	Time Min.			
1620		7	450	0-60,000	5-6

Table II - Effect of Applied Stresses on the Beginning and Ending Times of Isothermal Bainite Formation at 450°F, AISI 1085 Steel.

Applied Stress, p.s.i.	Ratio of		Ratio of	
	Time to form 1% bainite under no stress	Time to form 1% bainite under applied stress	Time to form 99% bainite under no stress	Time to form 99% bainite under applied stress
60,000		4		2.2

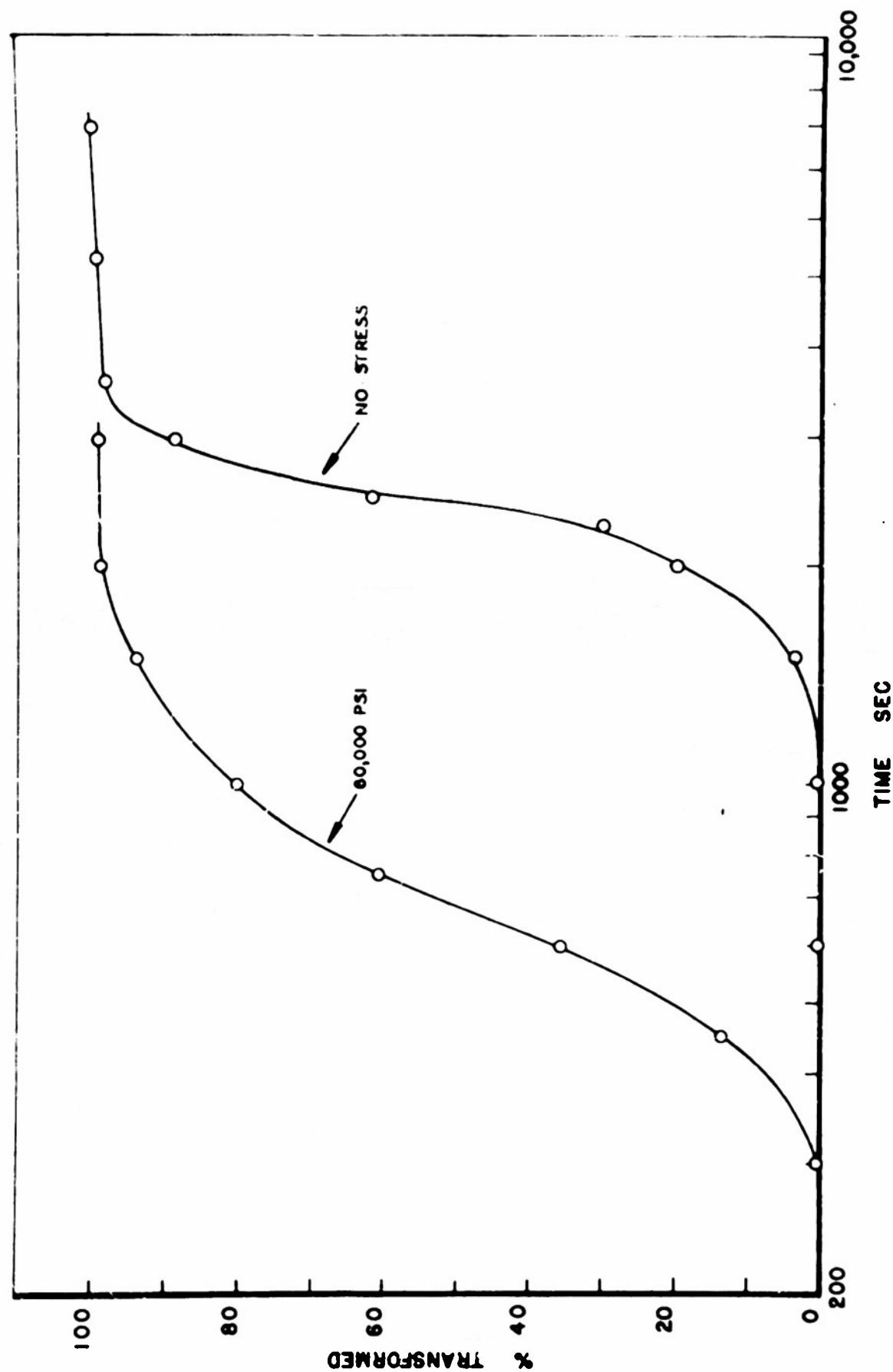


FIG. 1 AISI 1085 STEEL, ISOTHERMALLY TRANSFORMED AT 450°F

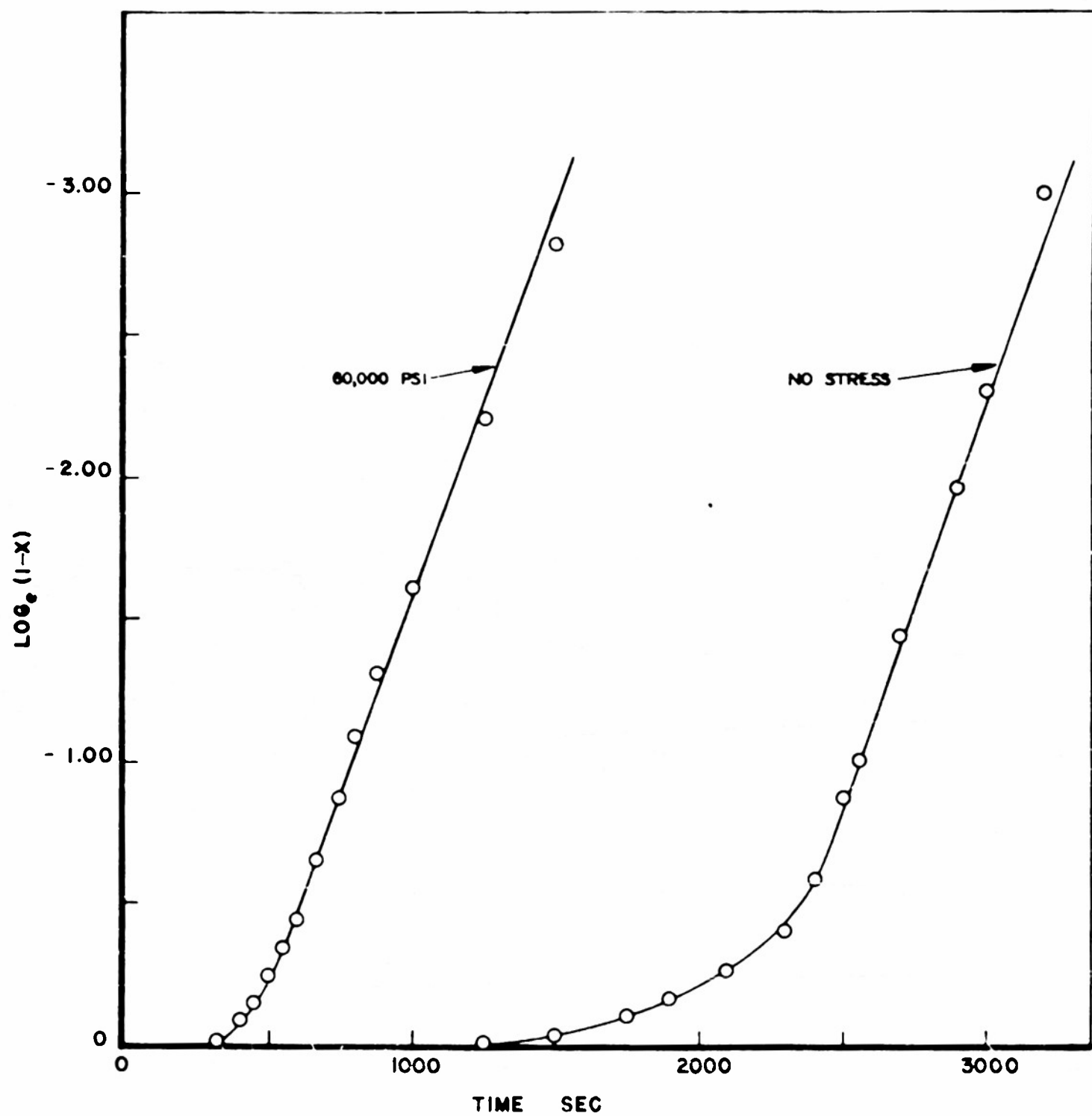


FIG. 2 RELATIONSHIP SHOWING THE VARIATION IN THE RATE OF DECOMPOSITION OF RESIDUAL AUSTENITE WITH APPLIED STRESS IN AISI 1085 STEEL, ISOTHERMALLY TRANSFORMED AT 450°F

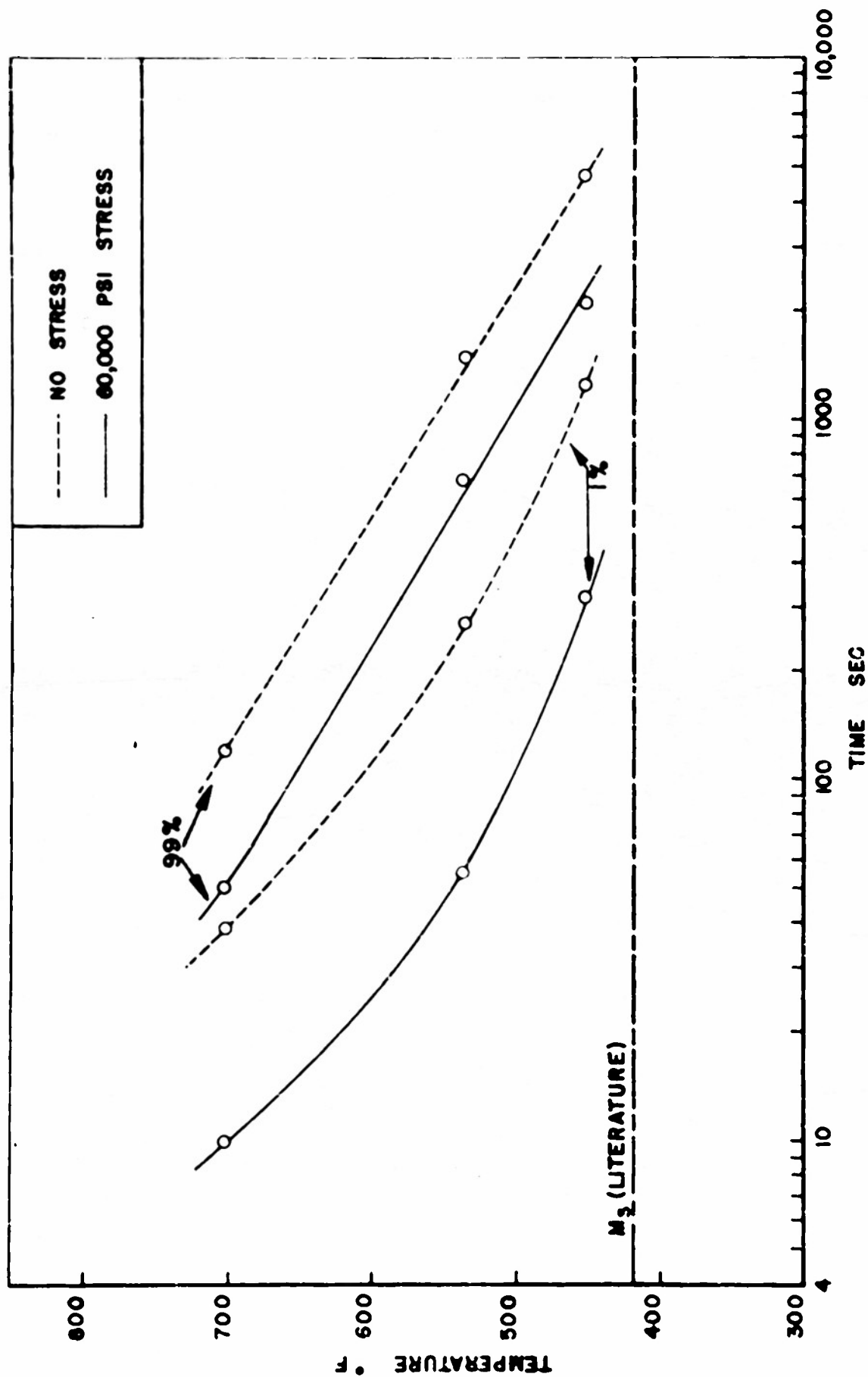
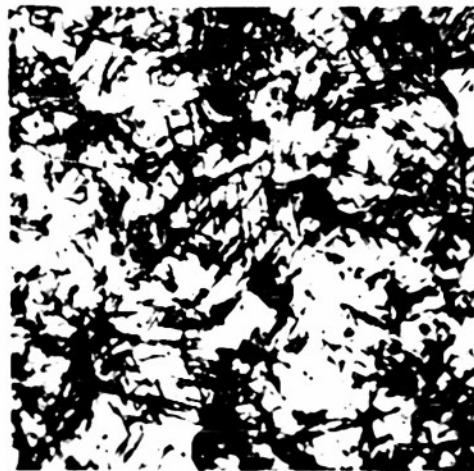


FIG. 3 T-T-T DIAGRAM OF AISI 1085 STEEL AS AFFECTED BY APPLIED STRESS IN THE REGION OF LOWER BAINITE



a. No stress: 2000 sec.

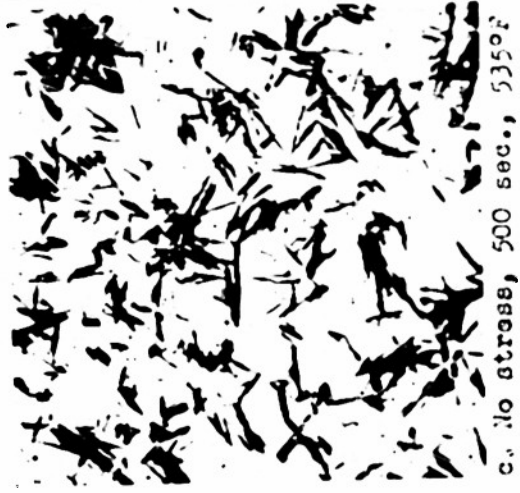


b. 60,000 p.s.i., 600 sec.

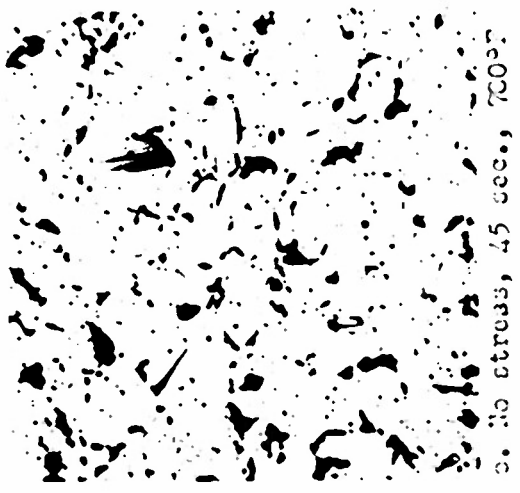
Fig. 4. Illustrating the effect of stress on bainite of AISI 1025 steel transformed isothermally at 450°F
Etchant - Saturated Picral 500 X



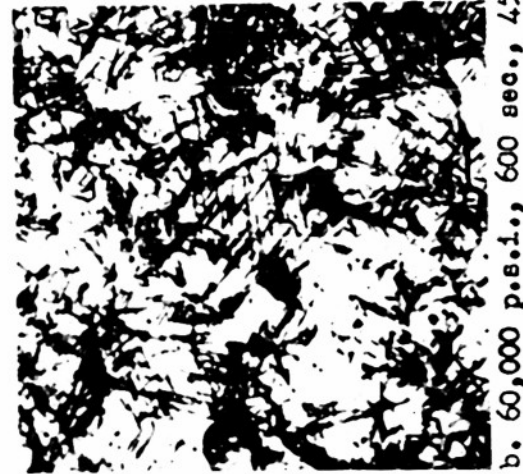
a. No stress, 2000 sec., 450°F



c. No stress, 500 sec., 535°F



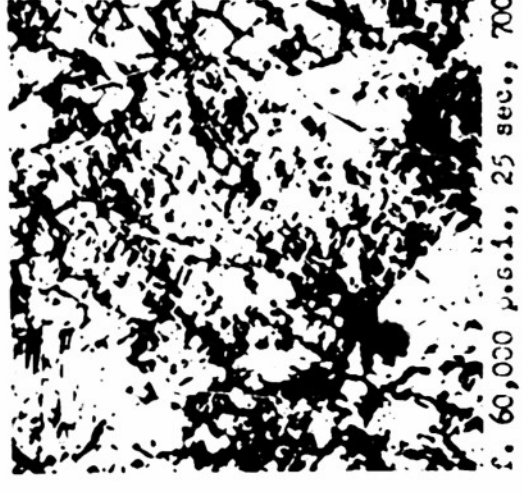
e. No stress, 45 sec., 700°F



b. 60,000 p.s.i., 600 sec., 450°F



d. 60,000 p.s.i., 120 sec., 535°F



f. 60,000 p.s.i., 25 sec., 700°F

Fig. 5 Illustrating a comparative study of microstructures of AISI 1085 steel transformed isothermally to partially bainitic structures at 450°F, 535°F, and 700°F
Etchant - Saturated Picral